Magnetic Subsystem Design and Testing for the NASA Magnetic Latching Cryogenic Coupler

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NASA AFRC

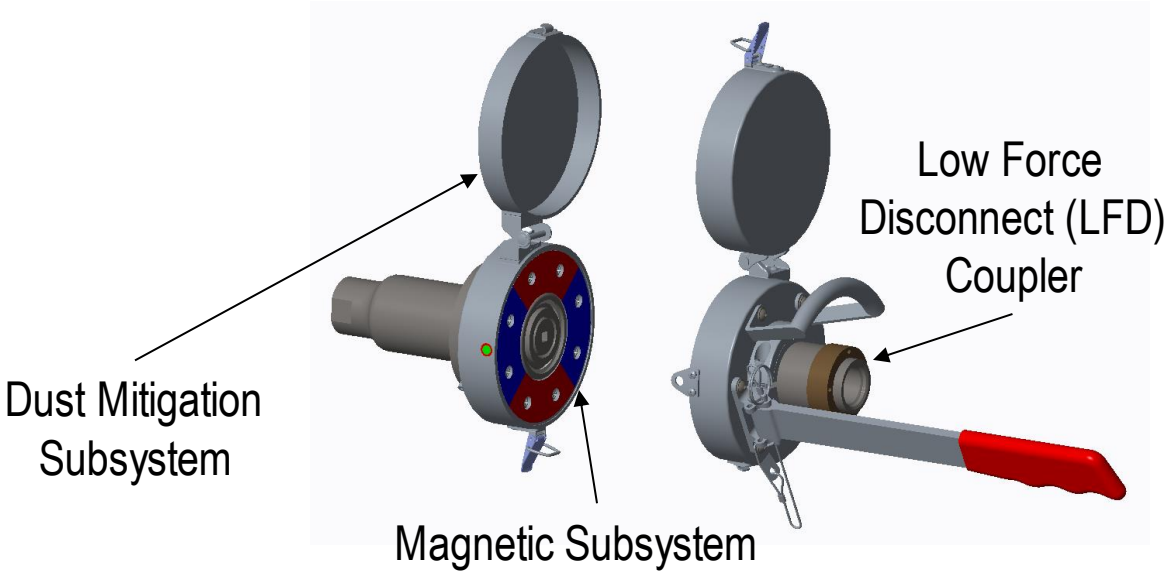
AIAA Scitech, 23-27 Jan 2023

Outline

- Magnetic latching cryogenic (CryoMag) coupler
  - Overview
  - Requirements
- Magnetic subsystem
  - Patterned magnetic interfaces
  - Design & operation
- Testing results
  - Thermal extremes
  - Force profile
- Conclusions & future work

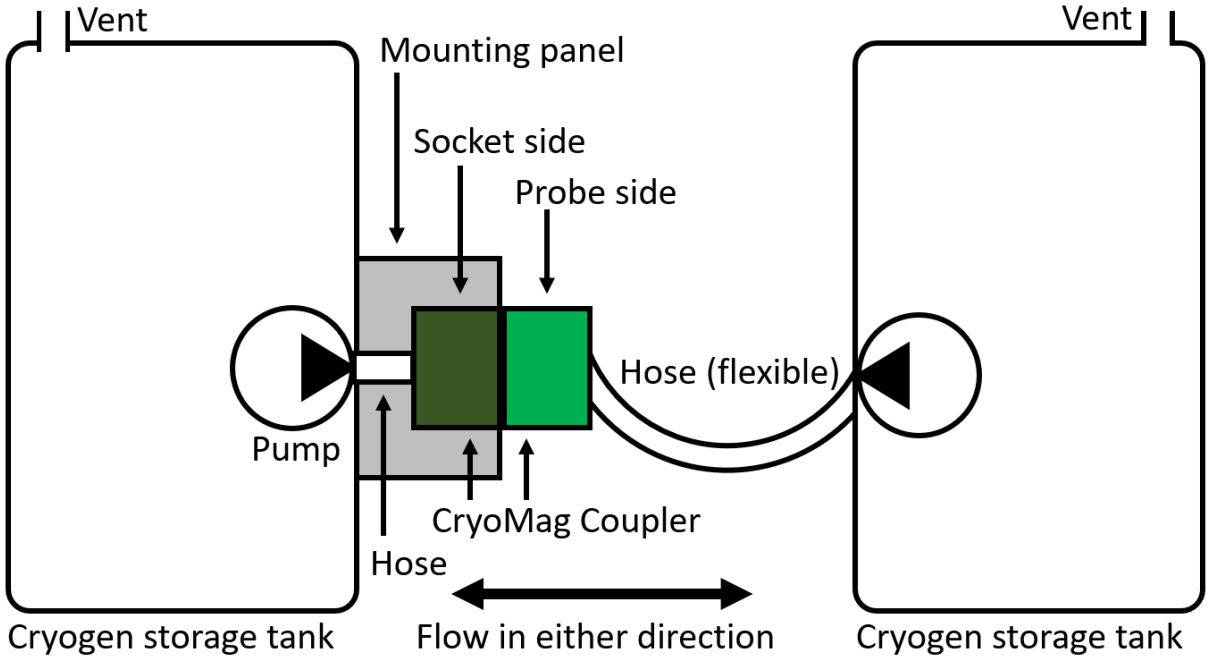
Cryogenic Magnetic (CryoMag) Coupler

- Quick-disconnect cryogenic coupler
- Magnets provide mating forces
- Operate in dusty (lunar) environment



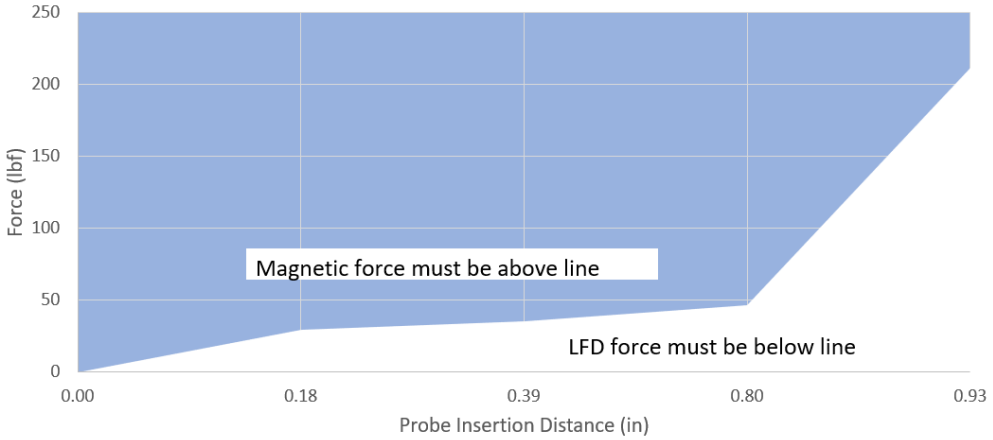
Operational Scenario

- Temporary connection between cryogen tanks
  - In-Situ Resource Utilization
  - Pressurized rovers
- LN_2 only for initial development

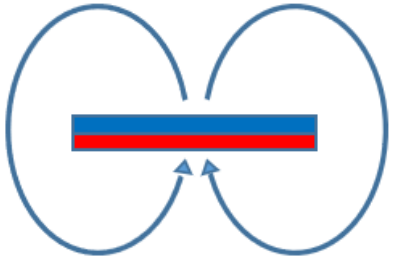


Requirements

- Lunar representative environment
  - Temperature range: -178°C to +127°C
  - Lunar regolith simulant dust surface loading
- Usability
  - Single-user operation
  - No external tools
- Interfaces between subsystems
  - Physical geometry
  - Force profile

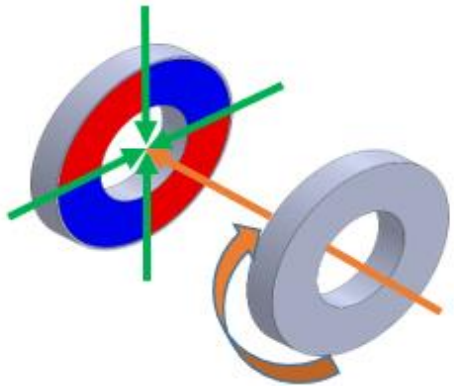


Patterned Magnetic Interfaces

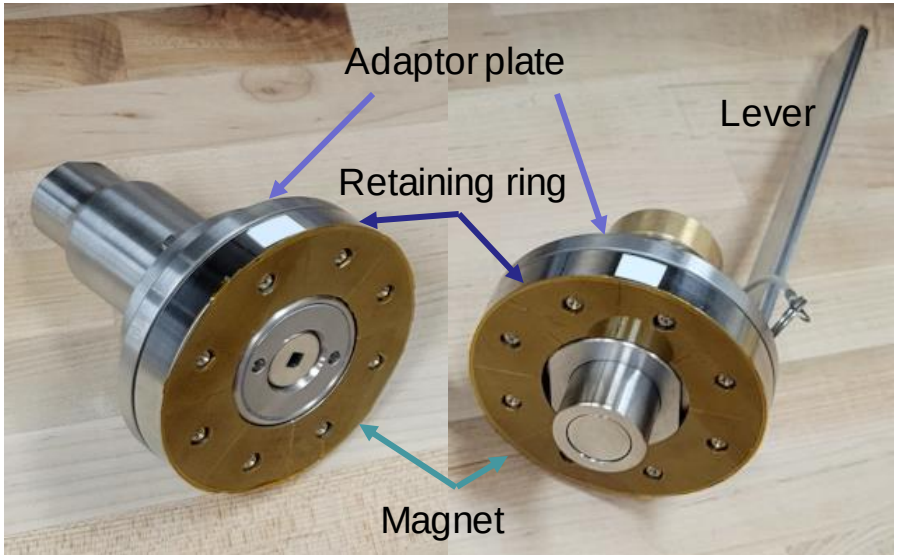


- Advantages
  - Reduced physical complexity
  - Assisted/automated mating
  - Self-alignment
  - Self-latching and reseating
  - Tailorable characteristics
  - Dust tolerance

- Disadvantages
  - Permanent magnet field
  - Lower holding force
  - Brittle material

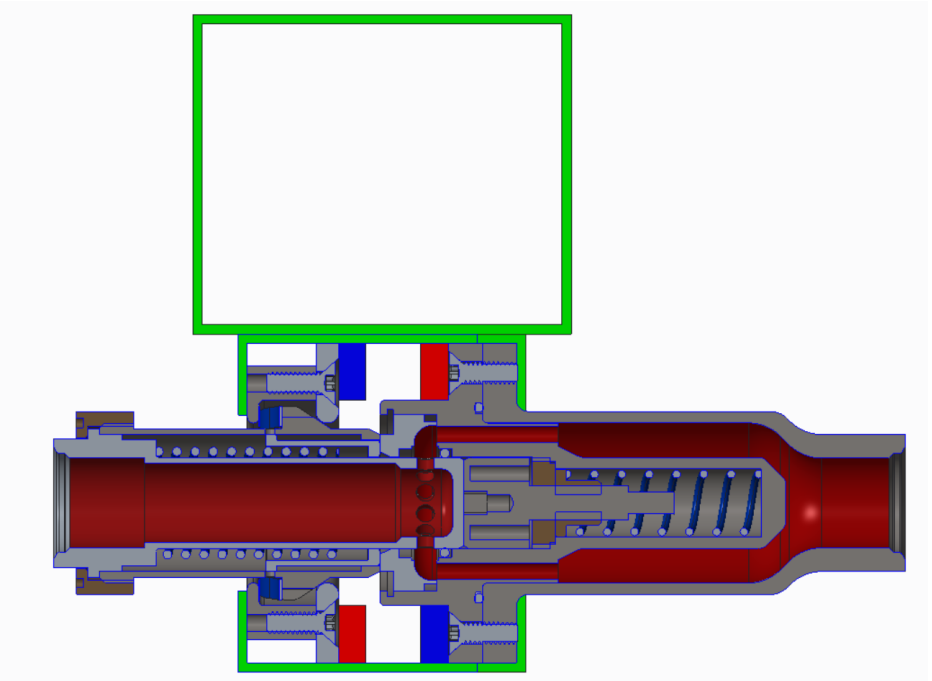


Design Overview



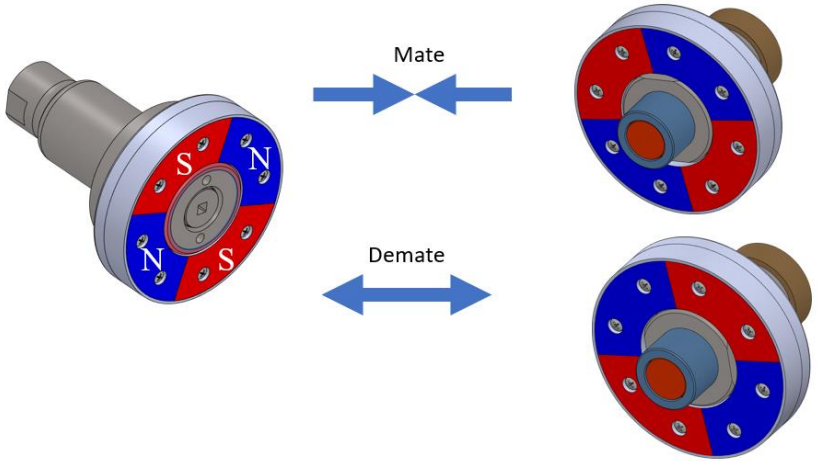
Socket

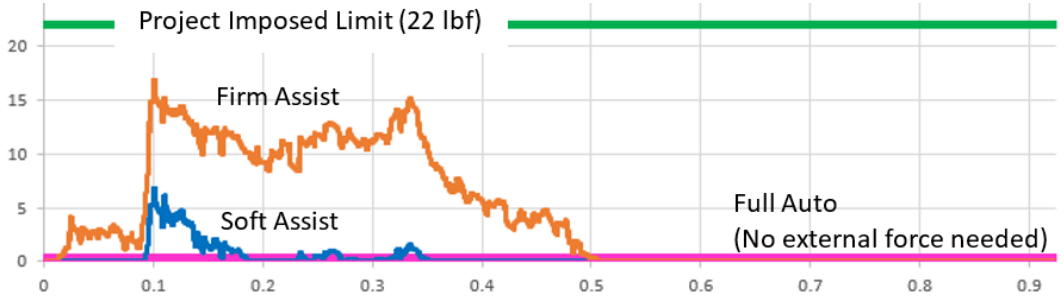
Probe



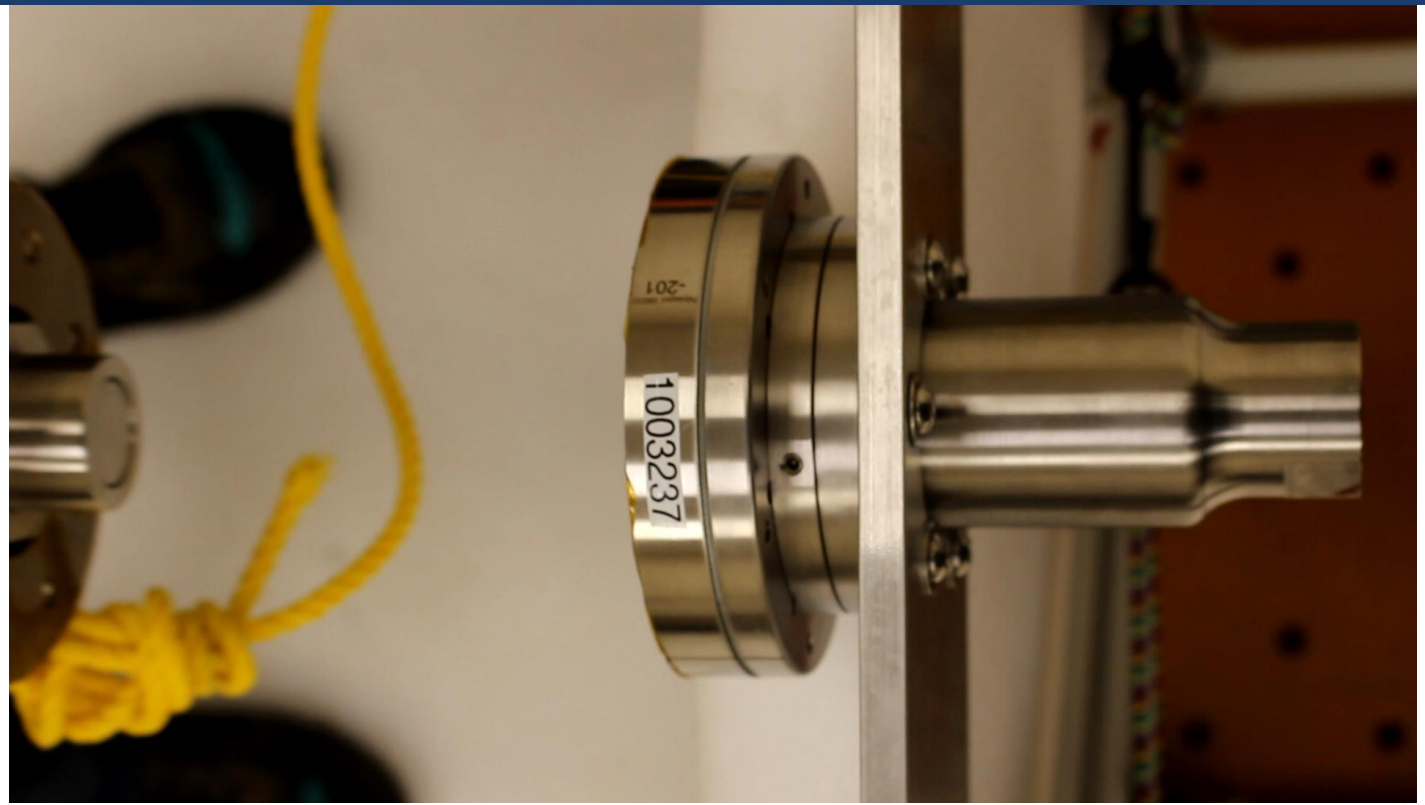
Magnetic Subsystem Operation

- Mate operation:
  - Poles are aligned
- Demate operation:
  - User twists coupler to un-align poles
- Magnet patterns/functions
  - Full auto
  - Soft assist
  - Firm assist

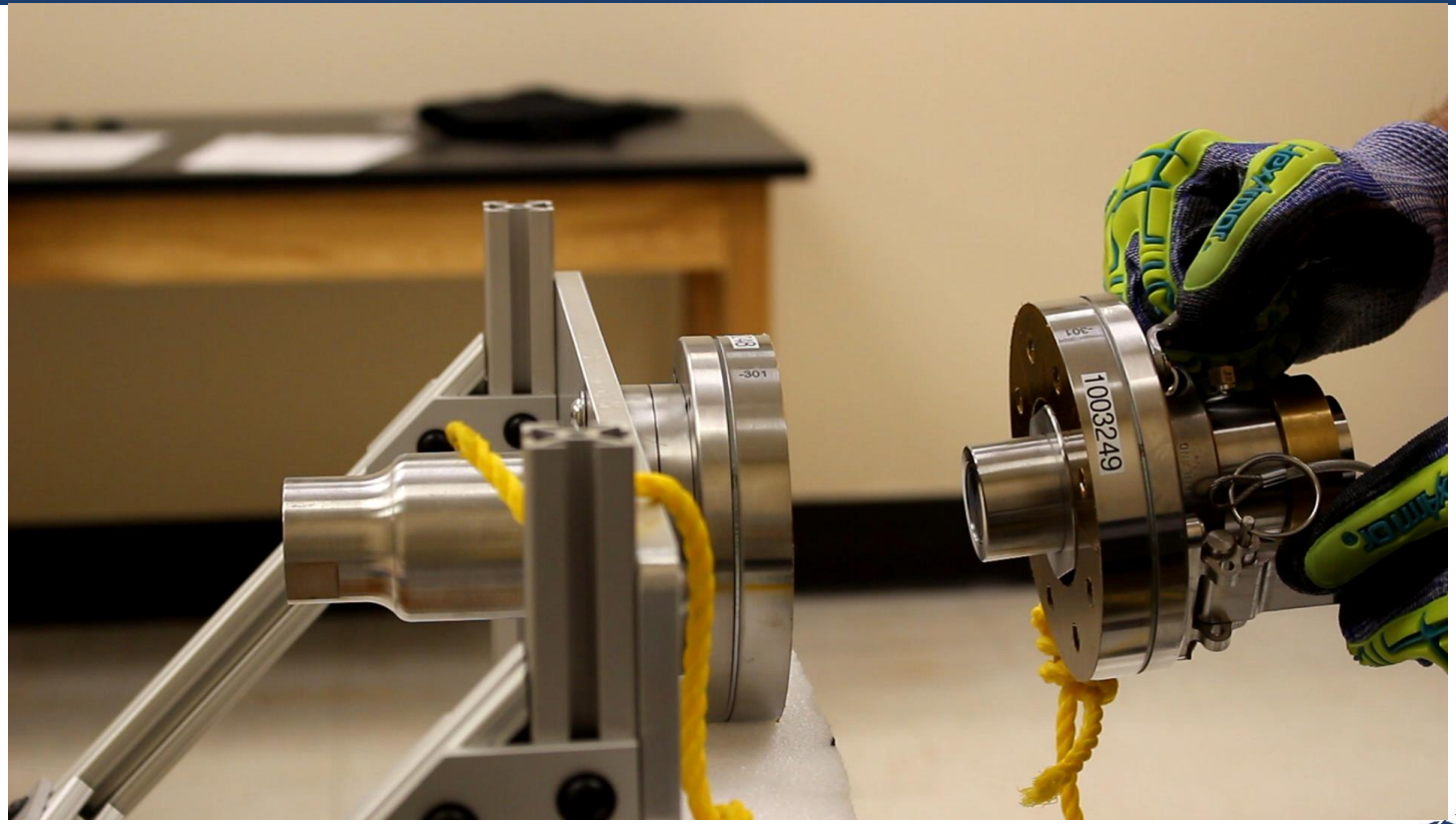




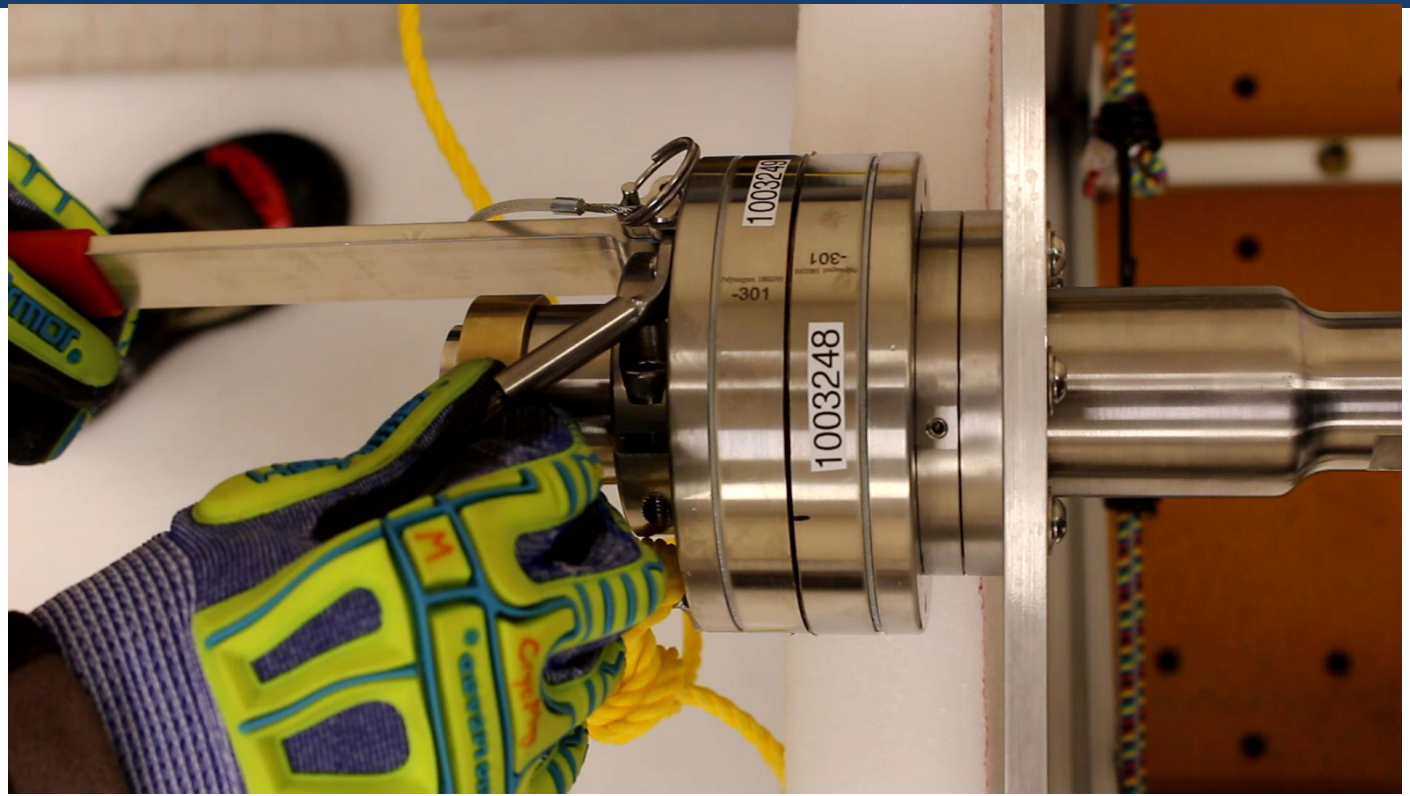
Full Auto



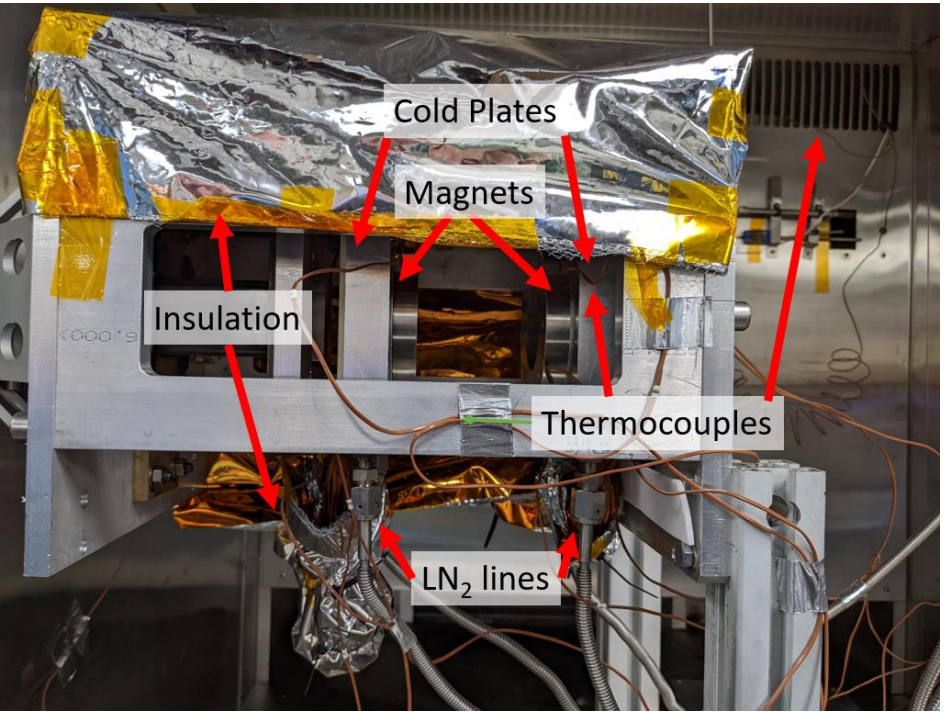
Soft Assist



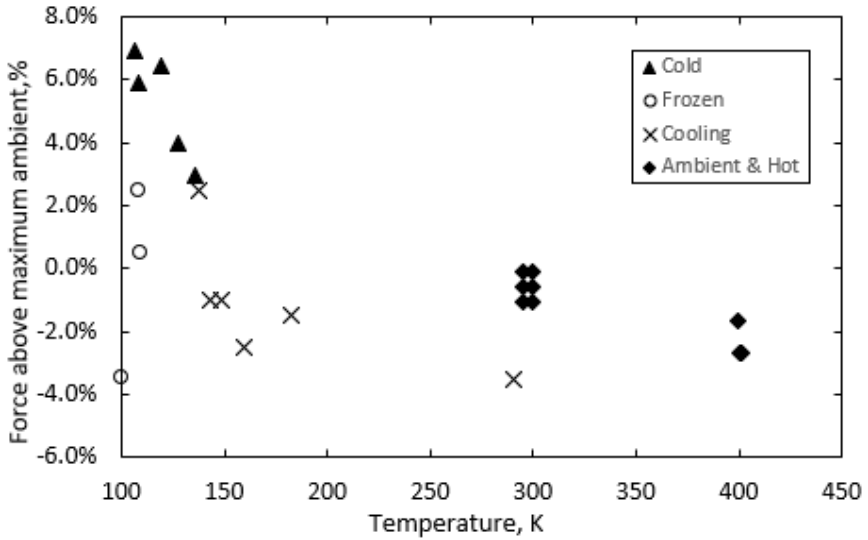
Demate



Test Results: Thermal

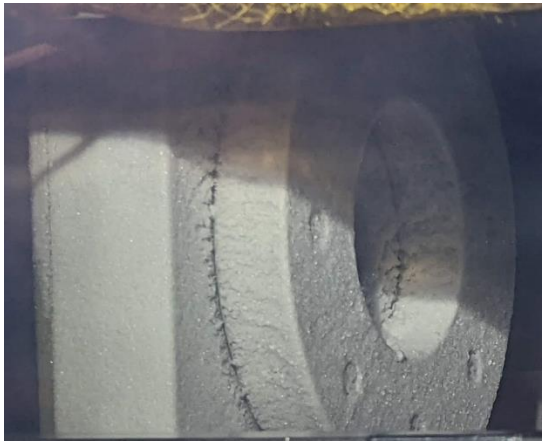


Attachment maximum force

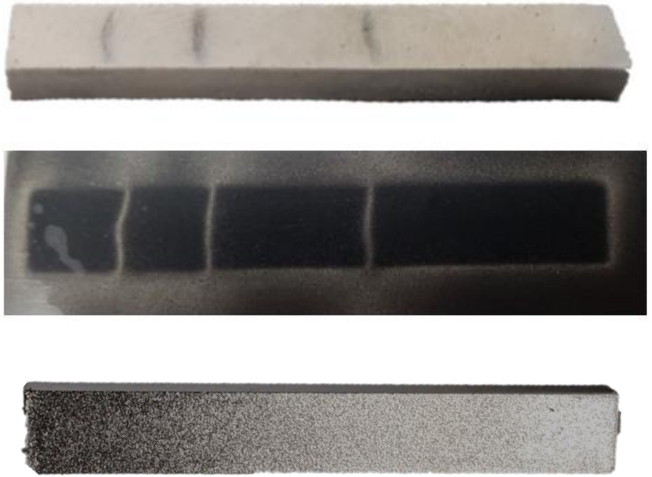


Test Results: Thermal

- Ice build up

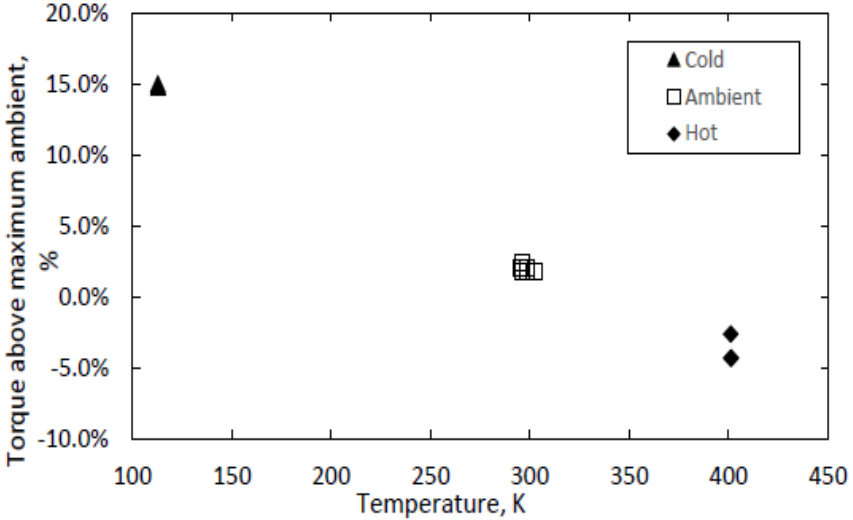


- Pattern visibility

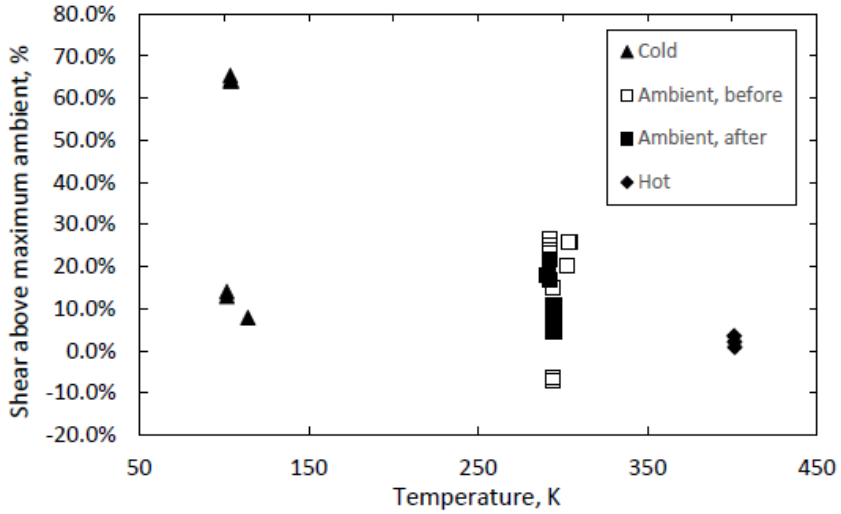


Test Results: Thermal

Torque



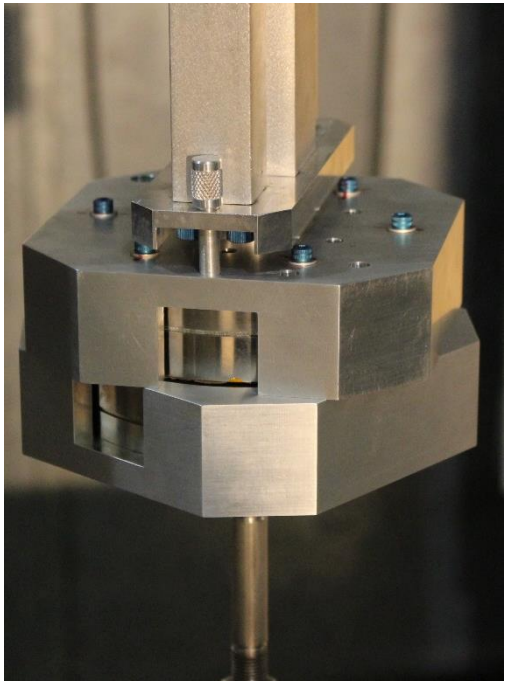
Shear



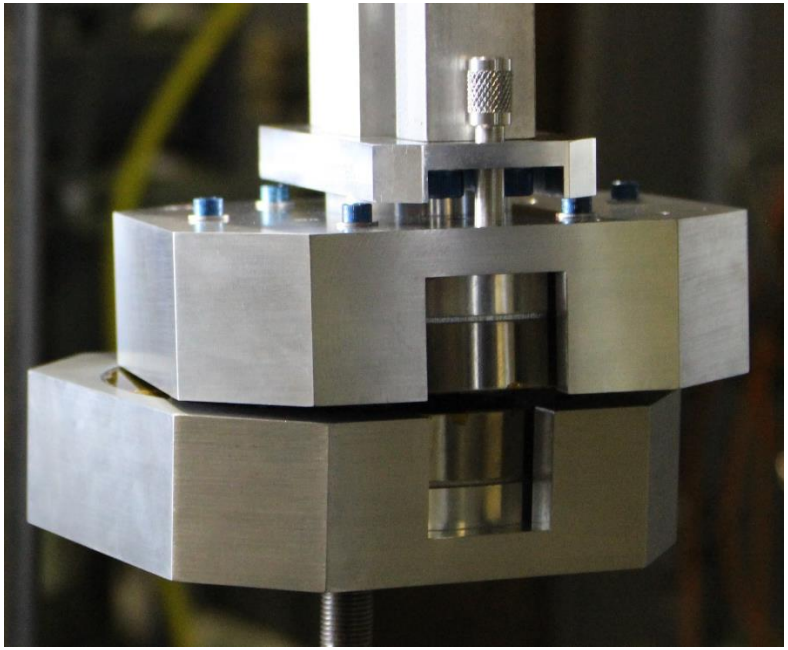
Test Results: Force Profile

Test Fixture

Demate orientation

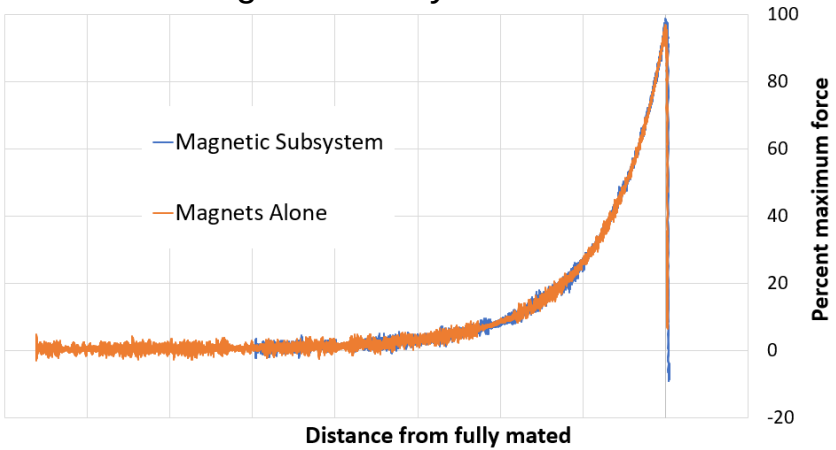


Off-nominal alternate alignment

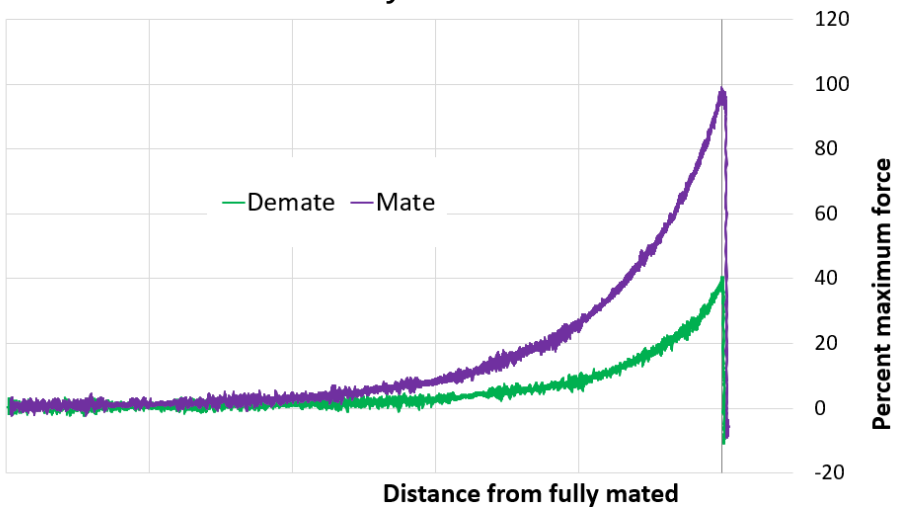


Test Results: Force Profile

Force profile of magnets alone versus Magnetic subsystem



Mate and demate force profile of Magnetic subsystem



Conclusions & Future Work

- Non-traditional mate/latch method developed using magnets
- Tested as part of CryoMag Early Career Initiative project
  - Thermal - successful
  - Force profile - successful
  - Integrated functional – in progress
- Potential future work
  - Coating evaluation
  - Pattern optimization
  - Testing in more-representative environments

Points of Contact

- Authors:
  - Paul Bean: paul.bean@nasa.gov
  - Nic Heersema: nicole.a.heersema@nasa.gov
- Related papers:
  - Manley, W., and Heersema, N., “Low Force Disconnect Cryogenic Coupler Design Development,” AIAA Scitech 2023
  - Stebbins, S., and Heersema, N., “Low-cost Testing in Representative Lunar Regolith Environment, “ AIAA Scitech 2023
- Interested in the technology?
  - Technology Transfer Office, NASA AFRC Edwards, CA 93523

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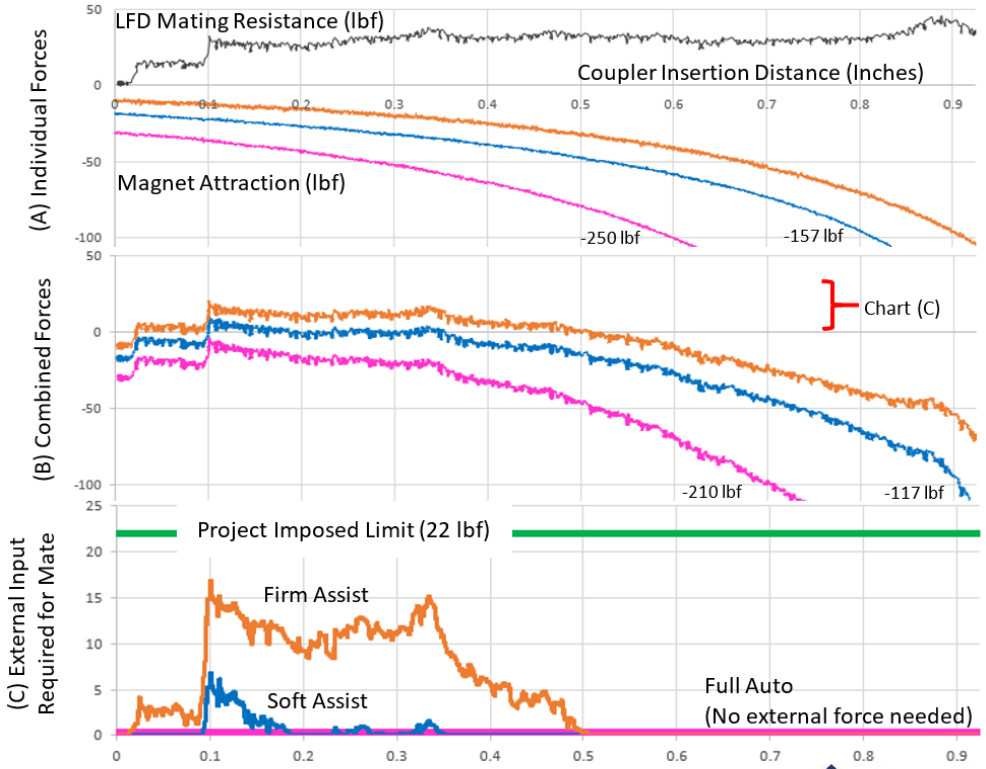
Backup

Pattern Selection

- Magnet patterns/functions
  - Full auto
  - Soft assist
  - Firm assist



Firm Assist